Tundra greenness

Epstein, Howard E.; Bhatt, Uma S.; Raynolds, Martha K; Walker, Donald A.; Forbes, Bruce C.; Phoenix, Gareth K.; Bjerke, J.; Tømmervik, Hans; Karlsen, Stein Rune; Myneni, R. B.; Park, T; Goetz, Scott J; Jia, Gensuo

Published in:
Bulletin of the American Meteorological Society

Published: 01.01.2018

Document Version
Publisher's PDF, also known as Version of record

Citation for pulished version (APA):
Epstein, H. E., Bhatt, U. S., Raynolds, M. K., Walker, D. A., Forbes, B. C., Phoenix, G. K., Bjerke, J., Tømmervik, H., Karlsen, S. R., Myneni, R. B., Park, T., Goetz, S. J., & Jia, G. (2018). Tundra greenness. *Bulletin of the American Meteorological Society*, *99*(8, Special Supplement), 165-169.
https://journals.ametsoc.org/doi/pdf/10.1175/2018BAMSStateoftheClimate.1

(Fig. 5.20; Duchesne et al. 2015; Smith et al. 2017). ALT in 2016 (most recently available data) was on average 0.06 m greater than the 2003–12 mean, similar to the previous peak value in 2012.

A decrease in ALT from 2016 to 2017 was reported for all Russian regions. In West Siberia, the average 2017 ALT was 1.25 m, which is 0.2 m (or 14%) smaller than the 20-year maximum observed in 2016. In the Russian European North, the 2017 ALT was 1.08 m compared to 1.24 m in 2016. A 2017 ALT of 0.69 m was reported for East Siberia, which is 0.1 m smaller than the regional average 2016 ALT value. The smallest decrease was reported in the Russian Far East (Chukotka), where the ALT in 2017 was 0.03 m (or 5%) less than that reported in 2016.

In the Nordic region, active layer records (1999–2017) indicate a general ALT increase of 0.10 to 0.30 m since 1999. The particularly warm summer of 2014 in the Nordic region contributed to the thickest active layer measured so far at some places.

h. *Tundra greenness*—H. Epstein, U. Bhatt, M. Raynolds, D. Walker, J. Pinzon, C. J. Tucker, B. C. Forbes, T. Horstkotte, M. Macias-Fauria, A. Martin, G. Phoenix, J. Bjerke, H. Tømmervik, P. Fauchald, H. Vickers, R. Myneni, T. Park, and C. Dickerson

Vegetation in the Arctic tundra has been responding to environmental changes over the course of the last several decades, with the tendency being an increase in the amount of above-ground vegetation, that is, "greening" (Bhatt et al. 2010). These vegetation changes vary spatially throughout the circumpolar Arctic in both direction and magnitude, and they are not always consistent over time. This suggests complex interactions among the atmosphere, ground (soils and permafrost), vegetation, and animals of the Arctic system. Changes in tundra vegetation can have important effects on permafrost, hydrology, carbon and nutrient cycling, and the surface energy balance (e.g., Frost et al. 2017; Kępski et al. 2017), as well as the diversity, abundance, and distribution of both wild and domesticated herbivores (e.g., Fauchald et al. 2017; Horstkotte et al. 2017). We continue to evaluate the state of the circumpolar Arctic vegetation, to improve our understanding of these complex interactions and their impacts on the Arctic system and beyond.

The reported controls on tundra greening are numerous and varied. They include increases in summer, spring, and winter temperatures and increases in growing season length (Bhatt et al. 2017; Fauchald et al. 2017; Horstkotte et al. 2017; Myers-Smith et al. 2018; Vickers et al. 2016), in part controlled by reductions in Arctic Ocean sea ice cover (Bhatt et al. 2017; Macias-Fauria et al. 2017; see Section 5d). Other controls on tundra greening include increases in snow water equivalent (see Section 5i) and soil moisture, increases in active layer depth (see Section 5g), changes in the patterns of herbivore activity, and even a reduction in the human use of the land (Fauchald et al. 2017; Horstkotte et al. 2017; Martin et al. 2017; Westergaard-Nielsen et al. 2017).

Using Earth-observing satellites with subdaily return intervals, Arctic tundra vegetation has been continuously monitored since 1982. Here, data are reported from the Global Inventory Modeling and Mapping Studies (GIMMS) 3g V1 dataset, based largely on the AVHRR sensors aboard NOAA satellites (Pinzon and Tucker 2014). At the time of writing, the GIMMS3g V1 dataset was only available through 2016. The GIMMS product (at 1/12° resolution for this report) is a biweekly, maximum-value composited dataset of the normalized difference vegetation index (NDVI). NDVI is highly correlated with above-ground vegetation (e.g., Raynolds et al. 2012), or "greenness," of the Arctic tundra. Two metrics based on the NDVI are used: MaxNDVI and TI-NDVI. MaxNDVI is the peak NDVI for the year (growing season) and is related to yearly maximum above-ground vegetation biomass. TI (time-integrated) NDVI is the sum of the biweekly NDVI values for the growing season and is correlated with the total above-ground vegetation productivity.

Examining the overall trend in tundra greenness for the now 35-year record (1982–2016), it is apparent that the MaxNDVI and the TI-NDVI have increased throughout most of the circumpolar Arctic tundra (Fig. 5.21). Regions with some of the greatest increases in tundra greenness are the North Slope of Alaska, the low Arctic (southern tundra subzones) of the Canadian tundra, and eastern Siberia. However, tundra greenness has declined (i.e., the tundra has been "browning") on the Yukon–Kuskokwim Delta of western Alaska, in the high Arctic of the Canadian Archipelago, and in northwestern Siberia. Regions of greening and browning, measured by NDVI increases and decreases, respectively, tend to be consistent between MaxNDVI and TI-NDVI.

Following 2–3 years of successive declines prior to and including 2014, the NDVI or greenness of Arctic tundra increased in 2015 and 2016 for both indices (MaxNDVI and TI-NDVI) and both continents (North America and Eurasia), exhibiting substantial recovery from the previous years of "browning." (Fig. 5.22). One exception was the TI-NDVI for North America, which continued to decrease in 2015. MaxNDVI and TI-NDVI for the entire Arctic increased 6.0% and 9.3%, respectively, between 2015 and 2016. MaxNDVI in North America increased by 6.3% compared to 5.4% in Eurasia. The first substantial annual increase in TI-NDVI for North America since 2010 occurred in 2016, potentially due to the high growing season temperatures that year.

All NDVI values for 2016 were greater than their respective mean values for the 35-year record. MaxNDVI values ranked second, third, and first for the Arctic, Eurasian Arctic, and North American Arctic, respectively. TI-NDVI values ranked first, first, and second for the Arctic, Eurasian Arctic, and North American Arctic, respectively. Based on remotely-sensed land surface temperatures (LST) from the same sensors as those providing the NDVI values, the summer warmth index (SWI: sum of mean monthly temperatures >0°C) for the Arctic as a whole and for the Eurasian Arctic was greater in 2016 than in any other year of the satellite record (since 1982). For the North American Arctic, the 2016 SWI was the second highest on record (very close to the highest value in 1994).

Even though the past two years have seen large increases in tundra NDVI, there are still regions of the Arctic that have experienced browning over the length of the satellite record. There have also been substantial periods of tundra browning even within a general greening trend. While research on tundra browning is still relatively sparse, there has recently been greater attention given to this phenomenon. Bjerke et al. (2017) report on extensive vegetation dieback in northern Norway (including Svalbard) in 2014 and 2015. They attributed this dieback largely to

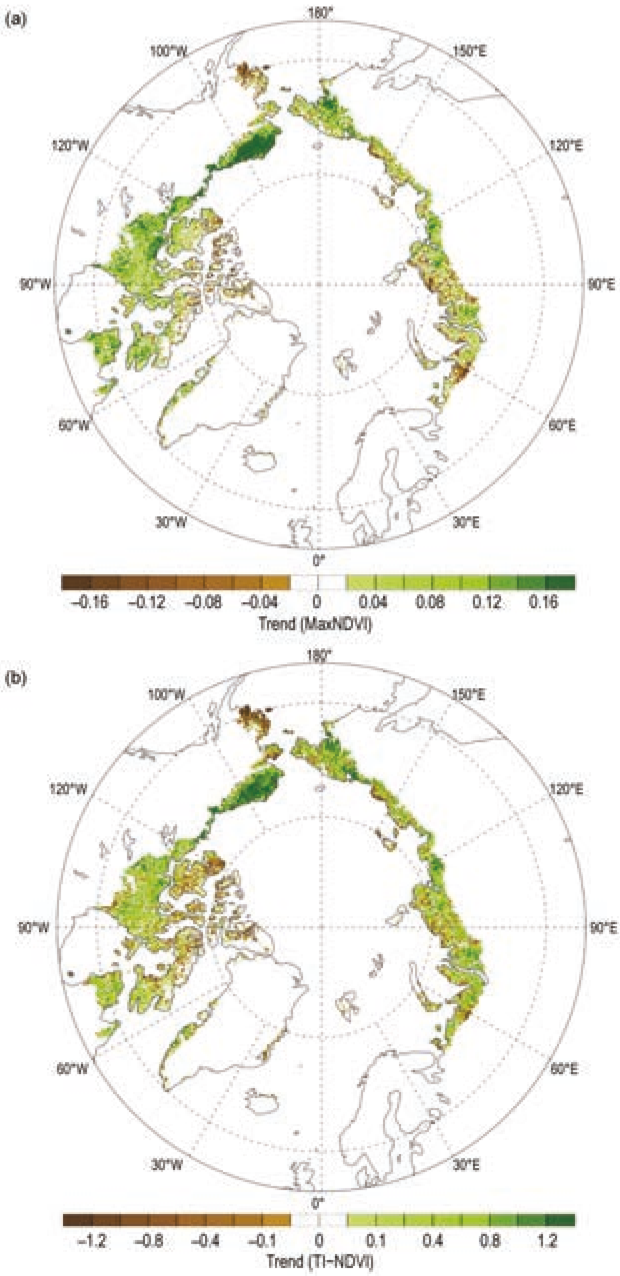

Fig. 5.21. (a) Magnitude of the trend in (a) MaxNDVI and (b) TI-NDVI for 1982–2016

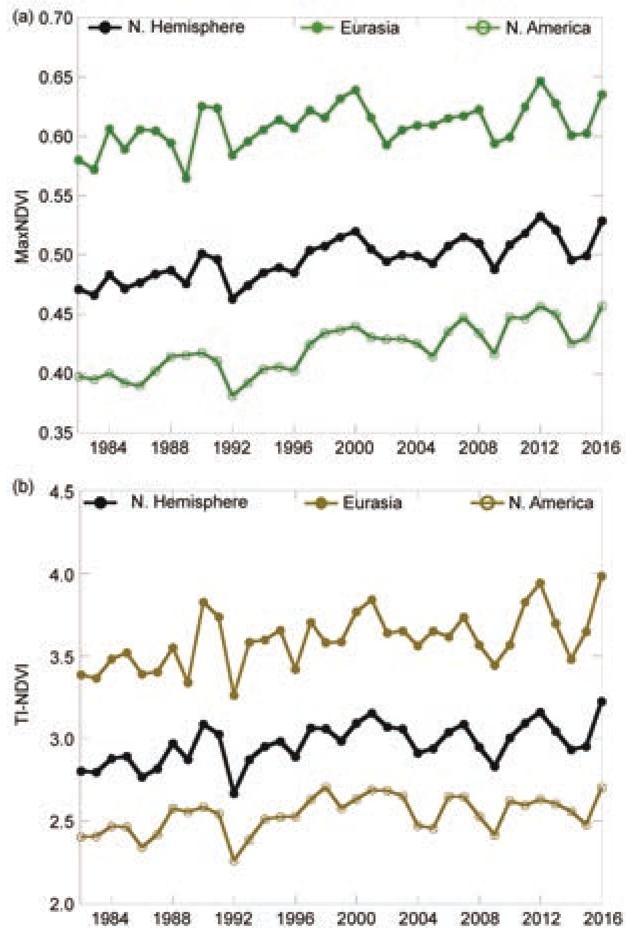

Fig. 5.22. (a) MaxNDVI and (b) TI-NDVI for Eurasia (top), the Arctic as a whole (middle), and North America (bottom) for 1982–2016.